Observations and Modeling of the West Florida Continental Shelf Circulation

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LONG-TERM GOALS

My long-term goal is improved understanding of how physical processes affect material property distributions on continental shelves. These include biological (red-tide algae and fish larvae), chemical (nutrients), and geological (sediment resuspension/transport) factors, and the physical responses of the currents and sea level.

OBJECTIVES

To achieve this goal I must accomplish a related set of objectives. In logical order these are. 1) I am developing a description of the seasonally varying circulations on the West Florida Continental Shelf (WFS). 2) Along with description, I am developing a quantitative understanding of how the various forcing functions: tides; synoptic weather; and surface, coastal, and offshore buoyancy fluxes affect these WFS circulations. 3) I am determining how these processes affect along and across-shelf material property transports, with emphasis on the surface and bottom boundary layers. 4) Given large seasonal transitions, I am assessing the relative importances between the surface fluxes (of heat and fresh water) and the coastal ocean dynamics (through horizontal advection and upwelling) in determining WFS water properties. 5) With better definition of the foregoing physical factors, I want to relate these findings to questions of geological, biological, and chemical importance; for example, storm surge prediction, sediment distributions and coastal erosion, nutrient distributions, species migrations and successions, the appearance of large scale regions of enhanced primary productivity, red-tides, and how all of these factors affect inherent optical properties (IOPs). 6) Since all of these objectives require sampling over various time and length scales using an assortment of instruments, I am working toward a WFS Autonomous Ocean Sampling Network (AOSN) site south of Tampa Bay that may be useful for naval defense related experimentation. 7) The support of AUV operations, testing of environmental sensors, and development of prognostic physical and biological models requires the capability for real time data which is an important continuing objective. 8) An aspect of near real time data retrieval is an optical transmission link between an AUV and a mooring for quick, reliable data transfer without the requirement for docking. 9) Finally, I want to observe the responses of the near bottom log-layer region across the inner shelf to assess sediment resuspension events and their effects upon water column IOPs.

APPROACH

My approach combines *in situ* measurements, remote sensing, and numerical circulation modeling. Along with colleagues, I have marshaled resources from several projects. The *in-situ* measurements

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

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1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **Observations and Modeling of the West Florida Continental Shelf Circulation**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of South Florida,Department of Marine Science,140 Seventh Ave. South,St. Petersburg,FL,33701**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

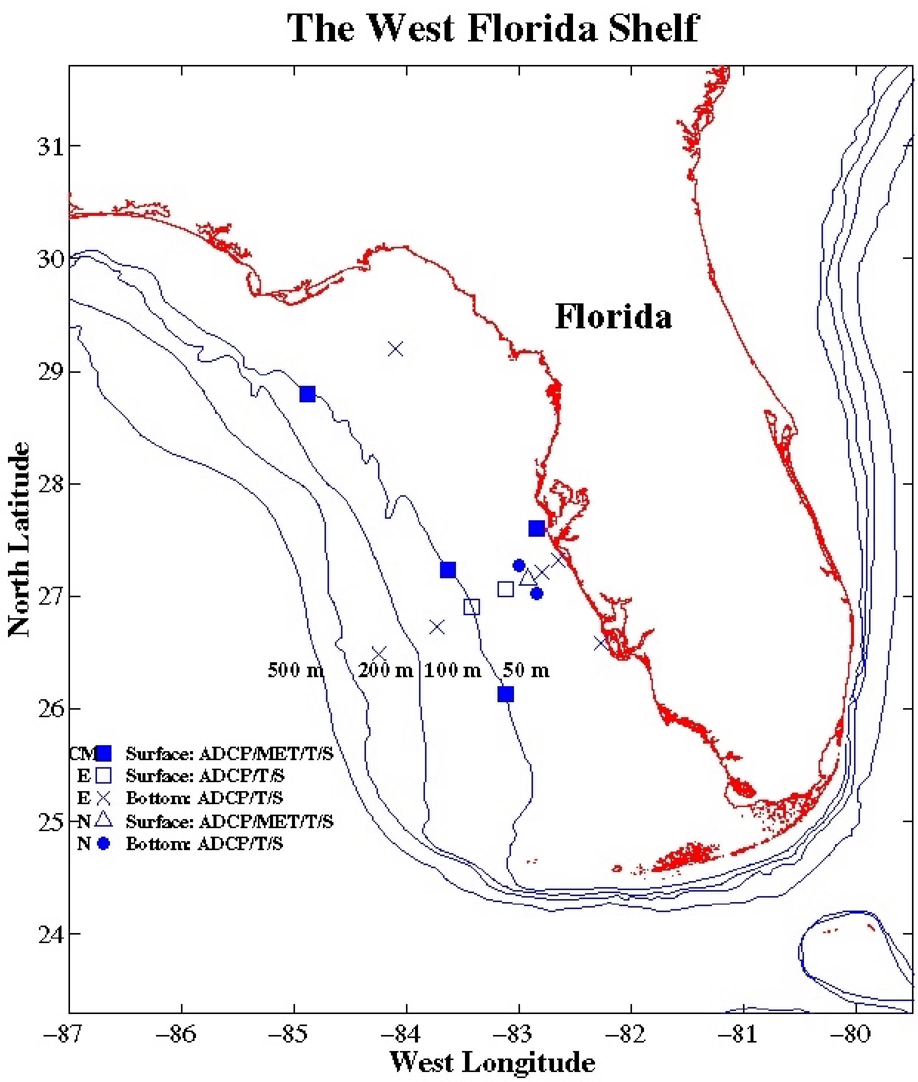
13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT **unclassified**	b ABSTRACT **unclassified**	c THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

consist of a moored array complemented by monthly hydrographic cruises. The array uses bottom and surface mounted acoustic Doppler current profilers (ADCP) for currents. The bottom moorings include temperature, salinity, and pressure sensors, and a smaller subset of these will include sediment resuspension packages (each with a near bottom array of acoustic current meters and optical instruments). The surface moorings include surface meteorological instruments and a vertically distributed set of either temperature/salinity (T/S) or temperature sensors. The array is shown in Figure 1.



The goal is to sample the inner shelf region and the spatial transitions that occur across the mid-shelf to shelf break. The main sampling line offshore from Sarasota FL is bounded by a control volume encompassing the region of Tampa Bay to Charlotte Harbor. Most of these measurements are by my USF Ocean Circulation Group (OCG). For sediment resuspension studies I am interacting with P. Howd and other USF geologists. Additional measurement sites are in the Florida Big Bend (with W. Sturges, FSU), and we are communicating with colleagues working in Florida Bay (T. Lee, RSMAS). Our monthly hydrographic cruises extend to the shelf break with lines running offshore from Tampa Bay, Sarasota, and Charlotte Harbor (with G. Vargo and J. Walsh, USF). These are augmented by Mote Marine Laboratory (G. Kirkpatrick) bi-weekly cruises offshore from Sarasota to the 30m isobath. Remote sensing includes satellite AVHRR and ocean color imagery (F. Muller Karger, USF). Numerical circulation modeling (within my OCG assisted by H. Yang and Z. Li) includes two regional versions of the Princeton Ocean Model. These models are limited to either the eastern Gulf of Mexico or the WFS so collaborations are underway with groups engaged in modeling the entire Gulf of Mexico (R. Patchen, Dynalysis and G. Mellor, Princeton University) or smaller scales (R. Garwood, NPS). Also at USF, J. Walsh is heading the biological modeling, K. Fanning is providing nutrient data, K. Carder anticipates deploying optics on the moorings (as does R. Maffione, HobiLabs), L. Langebrake [Center for Ocean Technology (COT)] developed the optical data transmission link, and my co-investigator M. Luther is assisting with the Florida COMPS system and our real time capabilites via the internet.

WORK COMPLETED

I initiated a WFS circulation study in 1993 in cooperation with the USGS Center for Coastal Geology. This expanded in 1995 with MMS and ONR support. The State of Florida approved a long-term plan for a Coastal Ocean Monitoring and Prediction System (COMPS) for real time monitoring of currents and surface fluxes offshore, and sea level and winds along the coast. USF, in partnership with others, was awarded an ECOHAB (Ecology of Harmful Algal Blooms) regional field study for the WFS by NOAA/COP, and this evolution allowed the development of the present efforts.

Measurements began with an ADCP at mid-shelf from 10/93 to 1/95. These data helped define the relevant time scales of motion and showed a seasonal cycle in the shelf circulation. Weisberg et al. (1996a, b) and in Black (1998) present some of these findings.

The pilot mooring was followed by a trans-shelf array of ADCPs deployed between the 300m and the 30m isobaths over the 8-12 month period 1/95-2/96. Data are reported in Weisberg et al. (1997) and Siegel (1998). They show an inner shelf region where responses to synoptic scale weather forcing are well-defined as contrasted with an outer shelf region where mesoscale interactions with the deep ocean are controlling.

To look more closely at the inner shelf, ADCPs were deployed off Sarasota FL on the 20m and 25m isobaths in 11/96. They show the three-dimensional nature of the inner shelf and the importance of baroclinicity even in shallow water. Seasonally, we observe a modulation of the across-shelf transports in response to wind forcing as the surface and bottom Ekman layers are affected by stratification. A seasonal cycle is also evident in the alongshore currents. Weisberg and Li (1999, in preparation) compare the *in-situ* data with a numerical model simulation for the seasonal transition month of 4/98.

Satellite imagery plays an important role. Weisberg (1994) related SST patterns to Loop Current influence on the WFS, and Siegel et al. (1999) expands on this. Weisberg, et al. (1999) report on a specific upwelling case study using satellite imagery, *in-situ* data, and a numerical model simulation. The case study winds were calm for several days prior to a wind-driven upwelling event, and this allowed us to view the response as an initial value problem. The observed Ekman/geostrophic spin-up, supported by dynamical analyses, shows the ageostrophic effects of the boundary layers under either stratified or constant density settings. Coastline geometry changes have large three dimensional effects.

Our numerical model applications are based on the Princeton Ocean Model of Blumberg and Mellor (1987). They include Lagrangian and Eulerian studies. Yang et al. (1999) describes Lagrangian experiments in an attempt to explain why surface drifters deployed in the northern WFS avoided the inner shelf region south of Tampa Bay. Li and Weisberg (1999a, b) describe model responses to upwelling favorable winds under constant density settings. The flow field kinematics are fully three dimensional with important regionality due to coastline and isobath geometries, and the flow field dynamics define the inner shelf and the momentum balance variations. We are beginning to explore with J. Walsh coupled physical/biological models of red-tide dinoflagellates.

The foregoing transitions directly into the present project. 12 of the 15 moorings shown in Figure 1 are deployed, the data returns are excellent, and we are achieving our measurement goals. The remaining three sites should be occupied by the spring transitional season of 2000. The array elements either record internally or telemeter data in real time. Our most complete telemetering mooring is on the 25m isobath with full surface heat and momentum flux information, water column currents, and T/S at six depths being transmitted hourly via GOES satellite and available on the internet. The data logger/transmitter for this mooring was designed and built by the USF/COT. We are in the process of building additional loggers, and we will add new fully telemetering systems as resources permit. Related work at Florida's SFOMC facility uses free wave radio telemetry, and our moorings there recently survived hurricanes Floyd and Irene. Along with the large scale array we initiated measurements of currents and sediment resuspension in the near bottom log-layer. We teamed with SonTec to test their new acoustic Doppler profiler (ADP) coupled with optical devices (LISST100 and OBS). A quadrapod was deployed on the 10m isobath off Sarasota FL adjacent to our conventional mooring. It housed a SonTek ADV (a single point measurement 1m off the bottom), a SonTec ADP (profiling at 10cm increments within 1.2m of the bottom), several temperature recorders, a LISST100, an OBS sensor, and a pressure recorder. The data are presently under analysis, and we are sharing results with P. Howd. With the USF/COT, we completed development and laboratory testing of an optical data transmission link for use between a mooring and an AUV. This allows for rapid data tranference as an AUV passes by a mooring. The system has of an axially symmetric transmitter with a vertical cone angle of 15° and a receiver. Laboratory tests (in air) gave reliable transfer rates of 57600 baud at distances of 20m. We are scheduling AUV time for in-water field tests.

RESULTS

FY99 results were achieved in all proposed areas. 1) The WFS array is in place. 2) Real time satellite telemetry capabilities are improved with a new operational logger/transmitter for meteorology, currents, and T/S. 3) Groundwork is laid for near bottom log-layer experiments using the latest optics and velocity profiling technologies. 4) A mooring to AUV optical data link is built and laboratory tested. 5) Numerical model experimentation is advanced for considering deep ocean-shelf interactions, seasonal modulation of inner shelf responses, and seasonal variability by local air sea fluxes.

Significant findings are as follows. 1) The WFS circulation is fully three dimensional, with variations in coastline/isobath geometry leading to regional upwelling centers. 2) The inner shelf (affected by isobath gradient) extends out to roughly the 50m isobath offshore of Sarasota FL, and stratification (by modifying the surface and bottom Ekman layers) strongly controls the along and across-shelf transports. 3) Although the inner shelf responds primarily to synoptic weather forcing, mesoscale interactions with the deep ocean are important by virtue of stratification influences. 4) The inner shelf seasonal cycle appears to be largely controlled by local buoyancy fluxes. 5) Modeling the inner shelf requires substantial support of *in-situ* measurements. Along with moorings, these must include surface, coastal, and offshore buoyancy fluxes and sufficient interior T/S profiles for assimilation, since without the density structure the model circulation will be incorrect. If the circulation is incorrect it follows that anything (nutrients, primary productivity, larvae distributions, inherent optical properties, sediment transport, etc.) that is dependent on more than a one dimensional balance will also be incorrect.

IMPACT/APPLICATIONS

Our physical oceanographic results are necessary inputs to biological/optical models. The fully three-dimensional, seasonally dependent WFS circulation responses, in particular the inner shelf, largely determines the chemical, geological, and biological properties to be sampled by sensors aboard AUVs or flown on satellites, including the COIS instrument planned for the NEMO satellite.

TRANSITIONS

The physical/biological modeling efforts will transition to WFS red-tide forecast model as part of the NOAA/EPA ECOHAB Program. Measurements and models are also being used for improved emergency preparedness as part of the COMPS Program.

RELATED PROJECTS

We are interacting with NOAA sponsored scientists to the south in Florida Bay (T. Lee) and with MMS sponsored scientists to the north in the Florida Big Bend (W. Sturges). The NOAA/EPA ECOHAB Program is co-located with our work (other P.I.s include J. Walsh, G. Vargo, K. Steidinger, G. Kirkpatrick). For HyCODE we are interacting with K. Carder, R. Maffione, and others, and for the larger Gulf of Mexico arena we are interacting with Dynalysis (R. Patchen) and Princeton (G. Mellor) scientists.

REFERENCES

Black, B.D. 1998. A description of the circulation on the west Florida continental shelf. Master of Science thesis, University of South Florida, August 1998, 135pp.

Blumberg, A.F. and G.L. Mellor. 1987. A description of a three dimensional coastal ocean circulation model. In *Three-dimensional Coastal Ocean models*, N. Heaps, ed. AGU, Washington D.C., 208-233.

Li, Z. and R.H. Weisberg (1999a). West Florida continental shelf response to upwelling favorable wind forcing, Part 1: Kinematics, J. Geophys. Res., 104, 13507-13527.

Li, Z. and R.H. Weisberg (1999b). West Florida continental shelf response to upwelling favorable wind forcing, Part 2: Dynamics, J. Geophys. Res., 104, 23427-23442.

Siegel, E.M. 1998. Currents observed across the west Florida continental shelf. Master of Science thesis, University of South Florida, April 1999, 155pp.

Yang, H., R.H. Weisberg, P.P. Niiler, W. Sturges, and W. Johnson (1999). Lagrangian circulation and forbidden zone on the West Florida Shelf, Cont. Shelf. Res., 19, 1221-1245.

Weisberg, R. H. 1994: Transport of Mississippi River water to the West Florida shelf. Special NOAA Rep., Coastal oceanographic effects of summer 1993 Mississippi River flooding, M. J. Dowgiallo, ed., NOAA Coastal Ocean Office, March 1994, pp55-59.

Weisberg, R. H., B. D. Black J. C. Donovan and R. D. Cole (1996). The west central Florida shelf hydrography and circulation study: a report on data collected using a surface moored acoustic doppler current profiler, Oct. 1993-Jan. 1995 Department of Marine Science, University of South Florida, St. Petersburg, FL.

Weisberg, R. H., E. M. Siegel, B. D. Black, J. C. Donovan and R. D. Cole (1997). The west-central Florida shelf hydrography and circulation study: a report on data collected using a trans-shelf array of acoustic Doppler current profilers, January 1995 - February 1996. DMS-USF tech. rep., May 1997.

Weisberg, R. H., B.D Black and H. Yang (1996). Seasonal modulation of the west Florida shelf circulation. Geophys. Res. Lett., 23, 2247-2250.

Weisberg, R.H., B.D. Black, and Z. Li (1999). An upwelling case study on Florida's west coast, (submitted and revised to J. Geophys. Res.).

PUBLICATIONS

Weisberg, R.H., B.D. Black, and Z. Li (1999). An upwelling case study on Florida's west coast, (submitted and revised to J. Geophys. Res.).

Siegel, E.M., R.H. Weisberg, F. Muller-Karger, and H. Yang (1999). Comparison between surface currents measured in situ and inferred from satelliteSST images on the West Florida Shelf, (submitted to J. Geophys. Res.).